

“On the Spectrum of the Spontaneous Luminous Radiation of Radium at Ordinary Temperatures.” By Sir WILLIAM HUGGINS, K.C.B., O.M., D.C.L., Pres. R.S., and Lady HUGGINS. Received July 17, 1903.

## [PLATE 8.]

The discovery of an element possessing such remarkable and novel properties as radium, which in its separate and distinct form as a new chemical element we owe to the researches of Professor and Mdme. Curie, has already thrown many beams of suggestive light into the very obscure regions of the constitution of matter. In radium we have a body which appears to be spontaneously and without ceasing giving off energy in several forms. According to Professor Rutherford,\* following upon the work of Becquerel, M. and Mdme. Curie, and others, the emanations going off from radium are at least of three kinds. First, an emanation of heavy corpuscles, larger in mass than the hydrogen atom, moving with a high velocity, and carrying a positive charge; secondly of negatively charged electrons which form a powerful and penetrating cathode emanation;† and further, of a radio-activity which diffuses from the radium as if gaseous in its nature. In addition, M. and Mdme. Curie have found that radium spontaneously maintains a temperature about  $1^{\circ}50$  C. above the surrounding temperature, and therefore emits heat radiations of wave-lengths falling within the infra-red part of the spectrum.

Now, in addition to these forms of radiant energy, the glowing of radium in the dark shows that it emits a luminous radiation spontaneously at ordinary temperatures. It appeared to us probable that in this glow we had not to do with either phosphorescence or fluorescence as usually understood, but with an independent and continuous radiation set up by those more active molecules which are supposed, in consequence of a condition of internal instability, to be the source of all the phenomena of radioactivity, and which can scarcely fail themselves to be violently agitated, in connection with disruptive molecular changes—especially the flinging off of the heavy corpuscles—during which, part of the energy stored up within the molecule is liberated in the kinetic form.

\* ‘Phil. Mag.,’ April and May.

† As an illustration of the penetrative power of the radio-active effects of pure radium bromide, the following experience may be recorded here. About 1 centigramme of radium bromide (Buchler & Co., Brunswick) had been placed in an upper drawer of my writing table, while in a lower cupboard of the same table was a store of photographic plates. After a week or two, all the plates, in boxes lying upon each other three or four deep, were found to be as completely fogged as if they had been exposed to light.

Taking this view of the luminous radiations visible to the eye, it seemed highly probable that the molecular motions by which they were set up, whether we suppose all the radium molecules alike to be concerned, or those only which are in active change, would be so far analogous to the vibrations produced artificially, when radium vapour is rendered luminous in a flame, or by the blow of an electric discharge, as, in like manner, to set-up radiations of certain definite wave-lengths or, in other words, to furnish a spectrum of bright lines.

A preliminary prismatic examination of the glow from pure radium bromide was attempted by eye. In consequence of the feebleness of the light under dispersion a slit spectroscope could not be used. A thin fragment of some length of radium was selected, which in the dark shone as a narrow line of light; when this was viewed through a direct-vision prism, it was seen to be dispersed into a spectrum which extended from the blue down to about D where it became too faint to be traced farther in the direction of the red. Within this faint spectrum certain spots were distinctly brighter, due, in all probability, to the presence of bright lines at those positions in the spectrum.

The success of this preliminary observation encouraged us to hope that it might be possible by availing ourselves of the accumulative power of continuous photographic exposure, to obtain a record of the blue, violet, and ultra-violet regions of the spectrum, if the glow radiations extended so far.

We made use of a small quartz spectroscope which had been constructed some years ago for very faint celestial objects. It consists of a compound quartz prism of  $60^\circ$ , consisting of two prisms of  $30^\circ$  of right-handed and left-handed quartz respectively. The quartz lenses are of short focus and of large angular aperture, being about  $\frac{1}{3}$  f. The focal length of the lenses is  $5\frac{3}{4}$  inches; they are plano-convex, the marginal parts of the convex surfaces being "figured" to diminish spherical aberration.

The solid radium bromide was placed at about a millimetre distance in front of the slit, which had to be wider than if a bright object was being photographed; the width was about  $\frac{1}{4 \cdot 50}$ th inch. In the case of the spark spectrum of radium and the comparison spectrum of nitrogen, a slit of less than half this width was used.

With an exposure of 24 hours, faint traces of two lines were seen on the plate. After several trials the negative reproduced on the accompanying plate was obtained with an exposure of 72 hours. The reproduction is enlarged two and a-half times. The spectrum consists of eight bright lines, and at least eight faint lines, together with a faint trace of continuous spectrum in the blue region, which does not come out in the reproduction.

It was seen at once that the two very strong characteristic rays of the spark spectrum of radium, in this part of the spectrum, namely,

3814.5 and 3649.6\* were not present on the plate. It was clear that the spectrum was not that of the radium molecule when excited by the electric discharge. It was indeed not improbable that if the radiation came alone from the most active molecules, which were suffering loss by material emanations, then if we may accept the analogy from sound, like a filed tuning-fork they would no longer give radiations of the same wave-lengths as before.

As soon as measures were taken of the lines it was found that several of them agreed in position within the uncertainty of the measures with lines in the spectrum of helium, but not with the most characteristic helium lines in this part of the spectrum. Now Rutherford and Soddy had pointed out† the almost invariable presence of helium in minerals containing uranium. It seemed, therefore, not impossible that we might have to do with helium contained within the radium bromide, and that this gas was being liberated in connection with the active molecules in a state of molecular vibration, analogous to that set up in gaseous helium by an electric discharge.

In consequence of the wide slit and the small scale of the spectrum, it is not possible to measure with certainty to the fourth figure, but the probable error is, we think, not greater than two units in the fourth place, that is  $\pm 0.0002$ .

[Received August 5.—Further examination of the new spectrum, stimulated by the unsatisfactory fact that the strongest lines of helium were not represented in the spectrum from radium bromide, has shown, quite unexpectedly, that if the new spectrum were slightly shifted relatively to the scale, then the seven strongest lines would agree not only in position, but also in relative intensity and character, with bands of the spectrum of nitrogen.

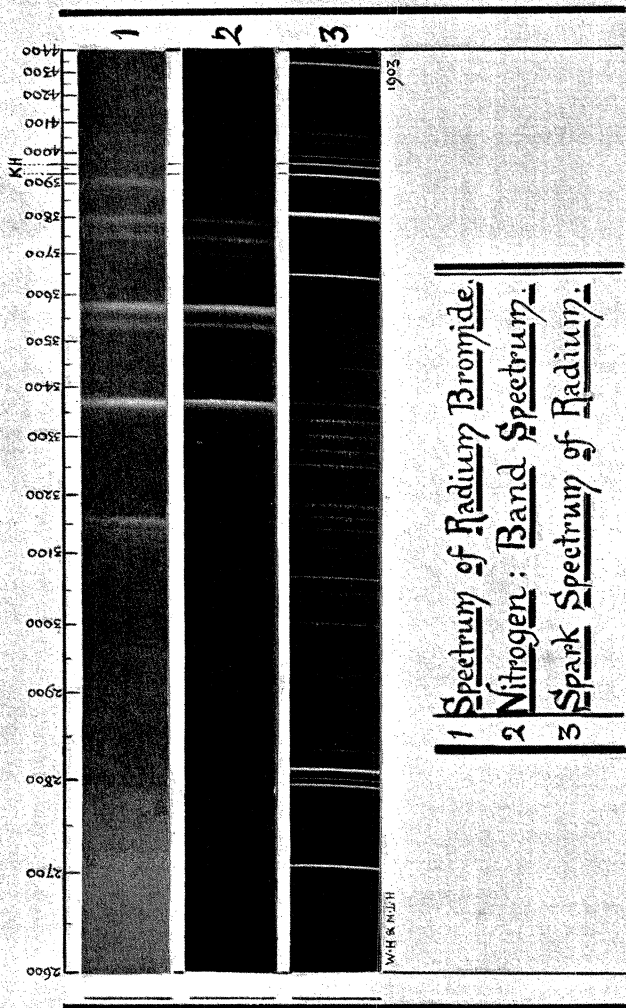
Now, the wave-lengths of the new spectrum had been found from a fiducial comparison solar spectrum, taken on the same plate. The slit is furnished with three shutters, of which the middle one only was open during the long exposure to the radium bromide. When the exposure was over, the middle shutter was closed, and the two side shutters opened, while the spectroscope was directed for a fraction of a second to the sky. As in both cases the collimator lens was filled with light, it was concluded that the wave-lengths would be correct. It is true that the spectroscope had to be placed in a different position for exposure to the sky, but as the instrument is very short and strongly constructed, it was not considered possible that any shift from flexure could arise.

The agreement with the bands of nitrogen is so complete that

\* For spark spectrum of radium, see Demarçay, 'Comptes Rendus,' vol. 129, p. 786, and vol. 131, p. 258; Exner and Haschek, 'Wien. Akad. Sitzber,' vol. 110, July, 1901; Runge, 'Astroph. Journ.,' vol. 12, p. 1.

† 'Phil. Mag.,' 1902, p. 582, and 1903, pp. 453 and 579.

# Spectrum of Radium Bromide



- 1 Spectrum of Radium Bromide.
- 2 Nitrogen: Band Spectrum.
- 3 Spark Spectrum of Radium.

though we are unable to trace any cause of shift, we feel justified in shifting the new spectrum on the diagram so as to bring the lines into agreement with those of nitrogen. The amount of shift at the position of the strongest line is nine tenth-metres, which, on the photographic plate, corresponds to the space of  $\frac{1}{150}$ th of an inch.

The positions of the three bands are, according to Ames,\* 3576·85, 3371·2 and 3158·9.

Indications of other lines, besides those which can be seen in the reproduction, can be faintly glimpsed on the negative. There seems little doubt that with a longer photographic exposure a more complete spectrum will be obtained. We have now secured some radium bromide prepared by the *Société Centrale de Produits Chimiques*, and it is our intention to take photographs of this salt, as well as photographs of the German salt, with longer exposures. It may then be, that indications of helium, and possibly of radium itself, may be forthcoming.

Nearly the whole of the ultra-violet radiations appear to come from nitrogen, and we think it best to refrain from any discussion at this moment. Have we to do with occluded, or with atmospheric nitrogen? The remarkable fact should be pointed out that in radium we have a body which at the ordinary temperature, sets up radiations which are similar to those which have hitherto only been obtained in connection with the electric discharge.

*Description of the Plate.*—At the top, is placed a scale of approximate wave-lengths. Immediately below is a reproduction, enlarged two and a-half times, of the spectrum obtained from the radium bromide with an exposure of 72 hours. As has been already explained this has been shifted to bring the lines into position with those of nitrogen photographed from a vacuum tube. The identity of the two spectra seems complete. The third band is faint in the nitrogen spectrum on account of the absorption of the glass of the tube.

Below, is a spark spectrum of radium bromide from the *Société Centrale de Produits Chimiques*. The H and K lines of calcium are present, as well as faintly some of the stronger lines of barium. The characteristic lines of radium at 3814·59 and 3649·7 come out strongly, as well as the strong line recorded by Demarçay at 4340·6. A strong line about 2710 was placed by Berndt† at 2708·6. The strong line a little beyond, about 2814, is due to radium. We do not recognise several lines recorded by Exner and Haschek‡ in this part of the spectrum.]

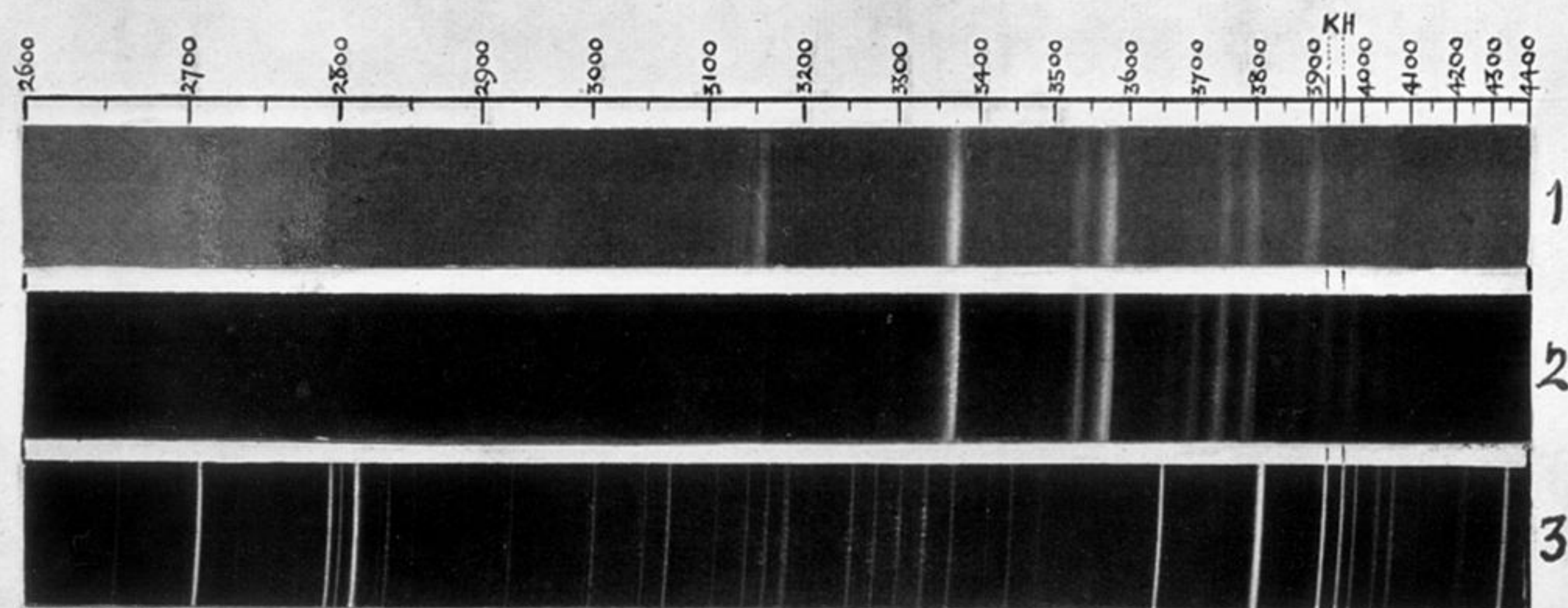
\* 'Phil. Mag.,' vol. 39, p. 57, 1890. See also Deslandres, 'Comptes Rendus,' vol. 101, p. 1256; and Percival Lewis, 'Astroph. Journ.,' vol. 12, p. 8.

† 'Phys. Zeitschr.,' vol. 2, No. 12 (1900—1901).

‡ 'Sitzb. Ak. Wiss. Wien,' vol. 110, July 4, 1901.



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